Electromagnetic Surveying of Brookhaven National Laboratories, Upton, New York

Senior Thesis

Submitted as a requirement for the degree
of Bachelor of Science in Geological Sciences

by

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Spring of 2000

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Acknowledgements

First and foremost I would like to thank Dr. Daniels for his guidance and support. I would also like to thank Jennifer Holt for her fine tuning abilities. Without either of you this would not have been possible.

Abstract

An electromagnetic survey at Brookhaven National Laboratories was conducted in order to locate pits hidden beneath the surface. The pits were used as waste disposal in the past and consequently their removal became necessary for health reasons. The two areas of study at the Upton, New York facility were named the Chemical/Animal Pits Area and the Glass Hole Pits Area. These areas were surveyed and the results processed to find the number and approximate lateral location of the pits in question. Using the conductivity to locate the pits as anomalies, the surveys located the pits.

The survey attempted to prove that electromagnetic surveying could be utilized to see into the ground and locate objects with a different conductivity than that of the medium it rested in. By running survey lines across the areas, the survey could systematically locate the pits by taking note of the positions of the anomalies that stood out in the earth.

The results of the survey were positive and the pits stood out markedly in the ground as anomalies. The data clearly shows the number of pits and their location along the grid in each area. The pits had their locations found correctly by the results from the survey and then were removed to prevent any further contamination of the ground. Other geophysical surveying was done at Brookhaven National Laboratories and the locations of the pits from those results match up very well with the data collected by the EM31 and EM61 electromagnetic surveying.

Introduction

Brookhaven National Laboratories is a scientific research center, located in Upton, New York. It was used to carry out various types of chemical experimentation for the Department of Energy, (Daniels and others, 1998). For almost twenty years, until the nineteen seventies, the

center disposed of their results into man-made pits. The holes were simply dug into the earth and not isolated from the soil. When filled, the pits were covered over with landfill. Consequently, over the time period of twenty-five years nature has reverted the surface back to a natural state and the locations of the pits have been lost. The insufficient isolation of the chemical waste from the groundwater has led to the leeching of the pits and the subsequent necessity to remove them. In addition, New York State has a low water table, and possible leeching of chemicals into the water table compounds the problem at Brookhaven to the point where removal of the pits has now become essential. In agreement with the health requirements set by the Federal Government and the state of New York, it is now necessary to find the locations and number of pits, along with their approximate depth and dimensions in the earth.

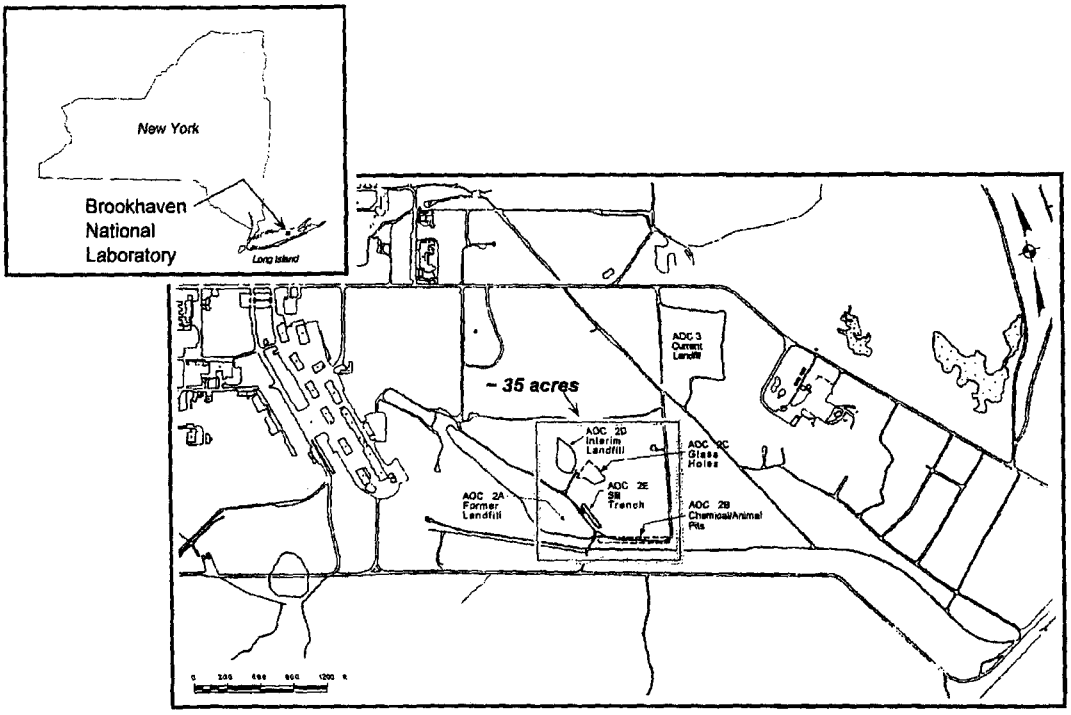

Figure 1: Map Overview of Brookhaven National Laboratories, from Sage Earth

Objectives

Only two sections of the Laboratory's waste area will be studied here. They are the Glass Hole Area and the Chemical-Animal Area, both consisting of numerous pits. These pits were filled with highly conductive oil drums, cans, and various other scrap metals, making it possible to use electromagnetism to identify them in the subsurface. The process of electromagnetic surveying was used to find the number of the pits and their approximate lateral extent in the subsurface in order for their removal. Using the EM31 and EM61 to determine the conductivity in the ground underfoot, and following a previously drawn grid, the process will systematically obtain enough information for the removal of the waste in the pits. Comparing these results to other, previously known data, such as aerial photos, maps, and conclusions of (Daniels and Brower, 1998), GPR survey, the locations and approximate subsurface boundaries of pits will be identified in order for their proper removal.

Background Information

Brookhaven National Laboratories is located in Upton, New York, on Long Island. The laboratory conducts research in physical, biomedical and environmental sciences and is under contract with the United States Department of Energy. It became necessary to excavate the pits in 1989 when it was put on the United States Environmental Protection Agency priorities list. The water table in the area of Brookhaven is from 30-45 feet, (Veatch, 1995) and shallow enough that the chemicals put into the pits could possibly be leaking into the water table and contaminating the drinking water of many people.

Geology of Area

Long Island is mostly flat, with hills to the north and east of the island. To the south, Long Island flattens to a marshy plain and then to a barrier beach. The bedrock that underlies all of Long Island is classified into two divisions. The first is the Fordham gray gneiss of Pre-Cambrian age, which is intruded by diorite. The next is the Stockbridge Dolomite of Late Cambrian to Early Silurian, (Merill, 1902).

The bedrock under Long Island was down-dropped as the rest of the bedrock plain on the mainland was raised up. This vertical separation between the Island and the mainland explains the depositional history of Long Island. In the Cretaceous, Long Island was covered by sea and the higher bedrock of the mainland was eroded, bringing sands and clays to the island. Over time, to the Tertiary, the area of Long Island was eroded and submerged, intermittently, and in the process eroded much of the Cretaceous rock, (Veatch, 1995). In the Quaternary, the ice sheet reached present Long Island and glacial till was dropped on top of the Island as the ice receded. This till consists of fine sands and much clay. The Brookhaven National Laboratory is underlain with 488 meters of unconsolidated sediments of fine to coarse quartzose sands with gravel resting on the bedrock, (Environmental Assessment Division, 1995). Most of the land that the Laboratory rests on is forest and relatively uninhabited. It is for this reason that the locations of the pits were easily lost after a number of years of non-agitation.

The taking of aerial photographs by survey companies at the time of emplacement makes it possible to see the digging, filling, and consequent covering of the pits in study. The entire process for filling each pit lasted less than a few years time and some were being revegetated near the end of their use. The aerial photographs show the pits to be circular in shape and four to six meters in diameter, (Environmental Assessment Division, 1995). There are no aerial

photographs to show the locations of the pits, for the Glass Hole Pits. These pits were dug after the final aerial photograph in 1972, (Environmental Assessment Division, 1995). The pictures show that the area of the pits was wooded before the time of excavation and returned to that state a few years after the digging was completed.

Description of Survey

Electromagnetic surveys of two areas were done at Brookhaven National Laboratories. The two areas were known as the Glass Hole area and the Chemical/Animal area. Because of the overgrowth of nature around the laboratories, the two areas were first leveled with bulldozers in preparation for these surveys. The area near the pits was relatively level with the exception of some sand push out piles. These however did not correspond to the locations of the pits. The land was leveled to increase accessibility and so that more accurate measurements could be made to the entire area. With a level base, the height of all the measurements could be taken as being relatively the same, thus eliminating any offset that would be caused by height differential in readings, possibly confounding the depth approximations.

After the preparation of the area, grids were drawn up in approximately north-south and east-west directions, (Daniels and others, 1998). For this project, GPR, magnetism, and other methods were used to identify the anomalies, so spacing was determined on a basis that would allow all of the non-intrusive geophysical methods to be used. It would then be possible to integrate the final results of each type of survey in order to reach agreement. Although more than one type of geophysical technique was used to explore the subsurface at Brookhaven, only the electromagnetic survey is discussed during this paper.

Electromagnetic data was collected at 2.5 meters apart along one profile and 5 meters apart on the profile that was in a direction perpendicular to the first. The data were taken at 2.5

samples per meter for the EM-31, and 3 samples per meter for the EM-61. Spacing for EM-61 was 1 meter. All measurements were done in the quadrature phase, or out of phase component, for the EM-31, (Geonics Limited, 1984). The out of phase component is affected with changes in conductivity in the subsurface. The method of transport was to manually move either of the instruments and walk along the grid. The measurements were taken at the intersection of each profile line using digital recordings controlled by the operator.

The EM31 is a coplanar, two coil, low frequency EM induction device used mainly for shallow observations. The EM61 is coaxial two coil transient EM device, 'seeing' deeper into the ground, but also used mainly for locating objects in the near surface.

Theory

The EM31 measures contrasting electric conductivities in near surface geology and detects buried metal objects in the ground, by the anomalies' reaction to magnetic fields. The device has an alternating current in the transmitter coil that creates a time varying magnetic field. It is this magnetic field that enters into the ground and induces very small electrical currents in the conducting body. These currents are known as eddy currents and they in turn create a secondary magnetic field, which are sensed, along with the primary magnetic field, by the receiver on the surface. The receiver measures the current induced by both the primary and secondary magnetic fields. Therefore the ratio of primary to secondary magnetic fields is linearly proportional to terrain conductivity, (McNeill, 1980). This fact makes the geology easy to interpret from the recorded data. In the case of Brookhaven National Laboratories, the subsurface is sandy soil with some clay content and ferrous objects stand out very well as high amplitude anomalies, which is easily shown on the contour plots, (Figures 4-7). The lower the resistance to the moving charges, the stronger the magnetic field sent back to the electromagnetic instru-

ment.

The apparent conductivity is given by:

$\sigma_a = (4)/(\omega * \mu_0 * s^2) (B_{sec} / B_{prim})$

μ_0 is permeability of free space

s is intercoil spacing, which is 3.7 meters, (Geonics Limited, 1984)

The EM instruments directly measure the resistivity in the ground, the anomalies create much stronger electric currents from the primary magnetic fields and therefore send off stronger secondary magnetic fields. Increase in conductivity at certain locations would identify that particular station as being part of the pit anomaly.

Presentation of Data

Chemical/Animal Pits

The pits are arranged in a mostly linear matter, trending in a northwest to southeast orientation. To the far northwest there is a grouping of high anomalous circles, which are too closely spaced to distinguish from one another. The EM61 plots show the area in better detail than the EM31. This type of massive anomaly is repeated to the South-West corner of the Chemical/Animal Test area and again is too much of a high plateau to distinguish. There is a grouping of pits at the 77475-395525 area. These conductivity highs are consistent with the size and shape of known holes in the area. Comparing the EM31 and the EM61 contours, there is at least nine separate pits in the vicinity and what appears to be three more to the immediate West of this grouping. The anomalies then trend to the southeast and continue to trend in that direction until completion. The locations and distribution of the data interpreted pits agrees with the before mentioned aerial photo data of the site and for the most part with the GPR survey done here, (Daniels and Brower, 1998). There are also many smaller anomalies that coin-

cide with the linear trend of the Chemical/Animal burial site. Not all of the pits in the southern-most row could be found, but along with the smaller anomalies, the cumulative data from the EM31 and EM61 show a good deal of the data. Figure 2 shows only a section of the known locations of the pits at the Chemical/Animal Pits, but it agrees with the contoured data.

The reason that historical records differ from the interpreted data is there is some amount of uncertainty to the historical data due to the age and quality of the photos. Also, there may be some pits that were not filled with conductive metals. Remnants of animal corpses and materials such as glass, wood, and plastic could have been buried in pits that don't show up on the survey as conducting anomalies.

Other anomalies that appear on the interpreted data could simply be objects buried out side of the delegated pit boundaries. This seems like a very possible explanation, agreeing with the mass burials that went on at Brookhaven.

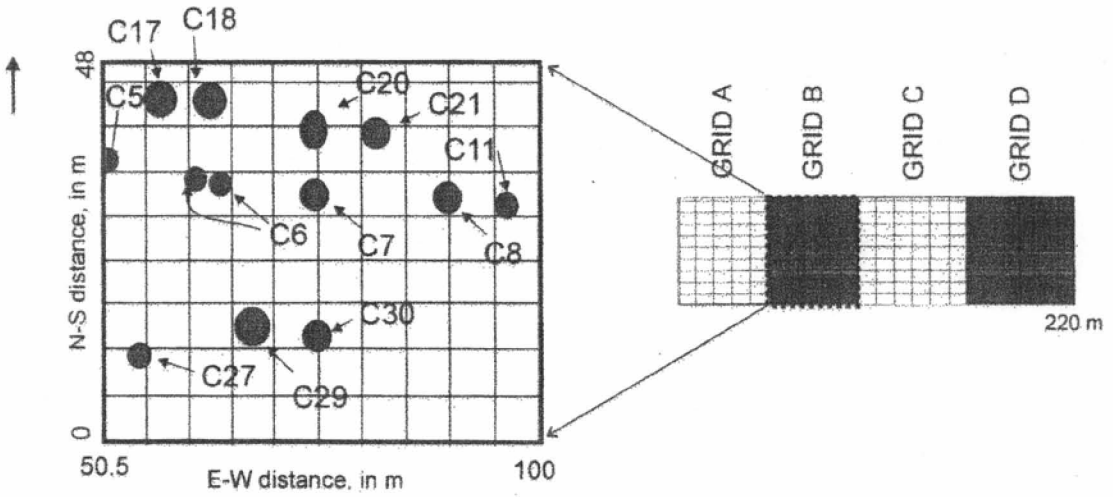

Figure 2: Pit locations for the Chemical/Animal Pit Area, from Daniels and Brower, 1998

Glass Hole Pits

The pits in this area are arranged in a horse shoe pattern, but there are a lot of anomalies outside of the semi-circular arrangement. A large anomaly fills the semicircular shape, with a strong line anomaly down the middle. The anomaly locations cannot be compared to previous aerial photographs, but the records at Brookhaven, (Figure 3), seem to match up with the contoured data. The sizes of the pits appear much larger than the four to six foot size that was expected. This area shows to be heavily laden with extra conductive materials that do not correspond to historical records of the locations of the pits. This is believed to be an old storage area, simply buried with sand and dirt.

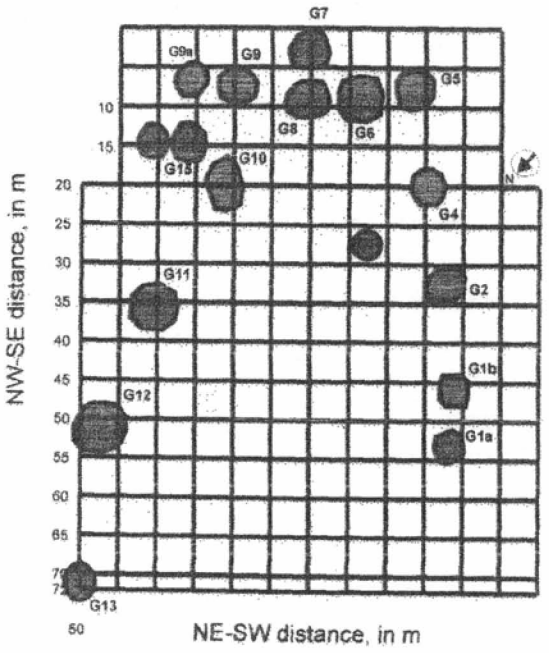

Figure 3: Pit Locations for Glass Hole Pit Area, from Daniels and Brower, 1998

The EM61 data shows the shape of the linear anomaly much better than the EM31. In contrast, the EM31 shows the horseshoe shape much better than the EM61. The horseshoe is consistent with what is expected in the Glass Hole Area, large anomalies in a semi-circular shape. To the North of the test area, there is another massive grouping of anomalies which are only interpretable as mainly linear in the West-East direction. As with the Chemical/Animal Area, there are various smaller anomalies that are outside of the main horseshoe shape; these could be locations of smaller pits in the area.

Conclusions

The measurements made by the EM31 and EM61 at Brookhaven National Laboratories shows that metallic objects in the subsurface can be readily identified from the sandy medium of the subsurface. The use of either EM survey alone makes for some ambiguous interpretation, and the locations of the various pits will not be so easily distinguishable. Based on previous data and photos, the approximate locations of the pits can be found, but the emphasis must be put on the correct interpretation of both of the data sets, (EM31 and EM61), combined. Correctly using both the EM31 and EM61 data together makes for a more complete interpretation of the Chemical/Animal and Glass Hole Areas. The EM31 shows the general trend and locations of the pits better, while the EM61 can show individual pit anomalies much clearer and more distinctly. The metallic objects at Brookhaven made the use of Electromagnetic surveying a precise and worthwhile endeavor.

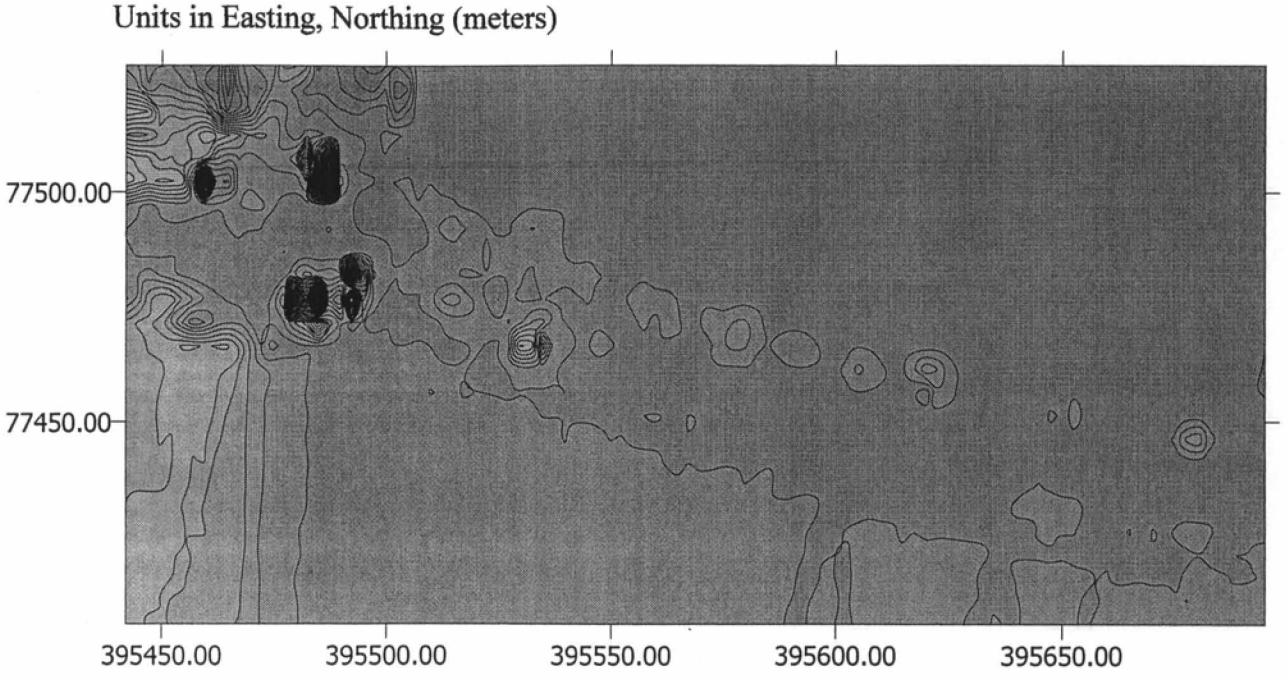

Figure 4: Summary Interpretation for the Animal/Chemical Site, EM-31

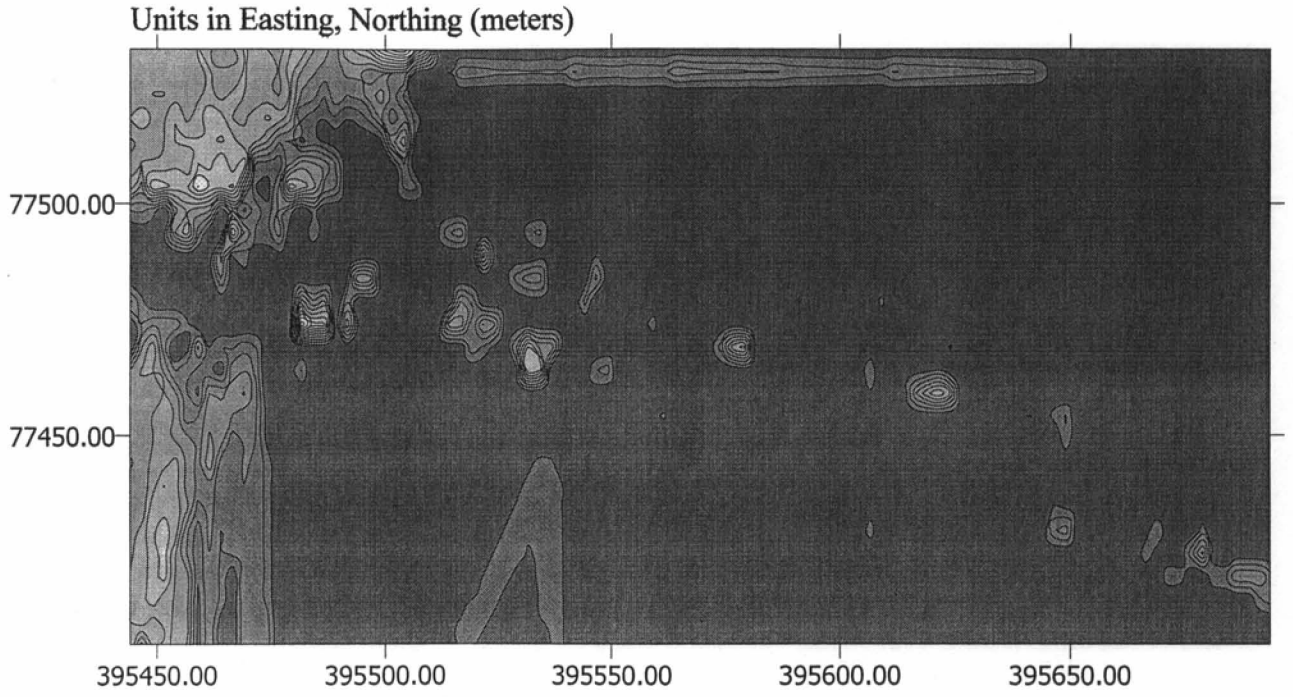

Figure 5: Summary Interpretation for the Animal/Chemical Site, EM-61

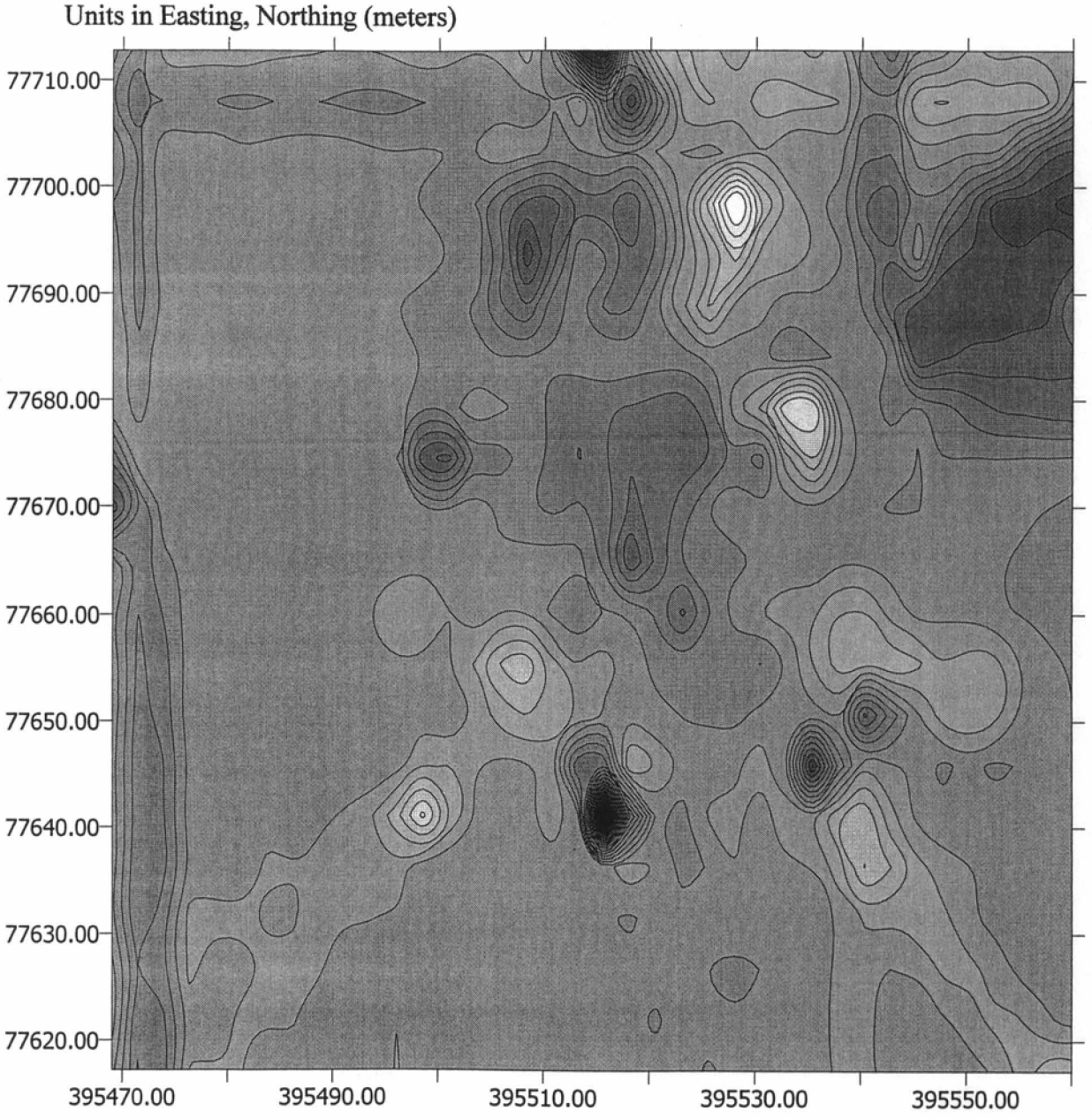

Figure 6: Summary Interpretation for the Animal/Chemical Site, EM-31

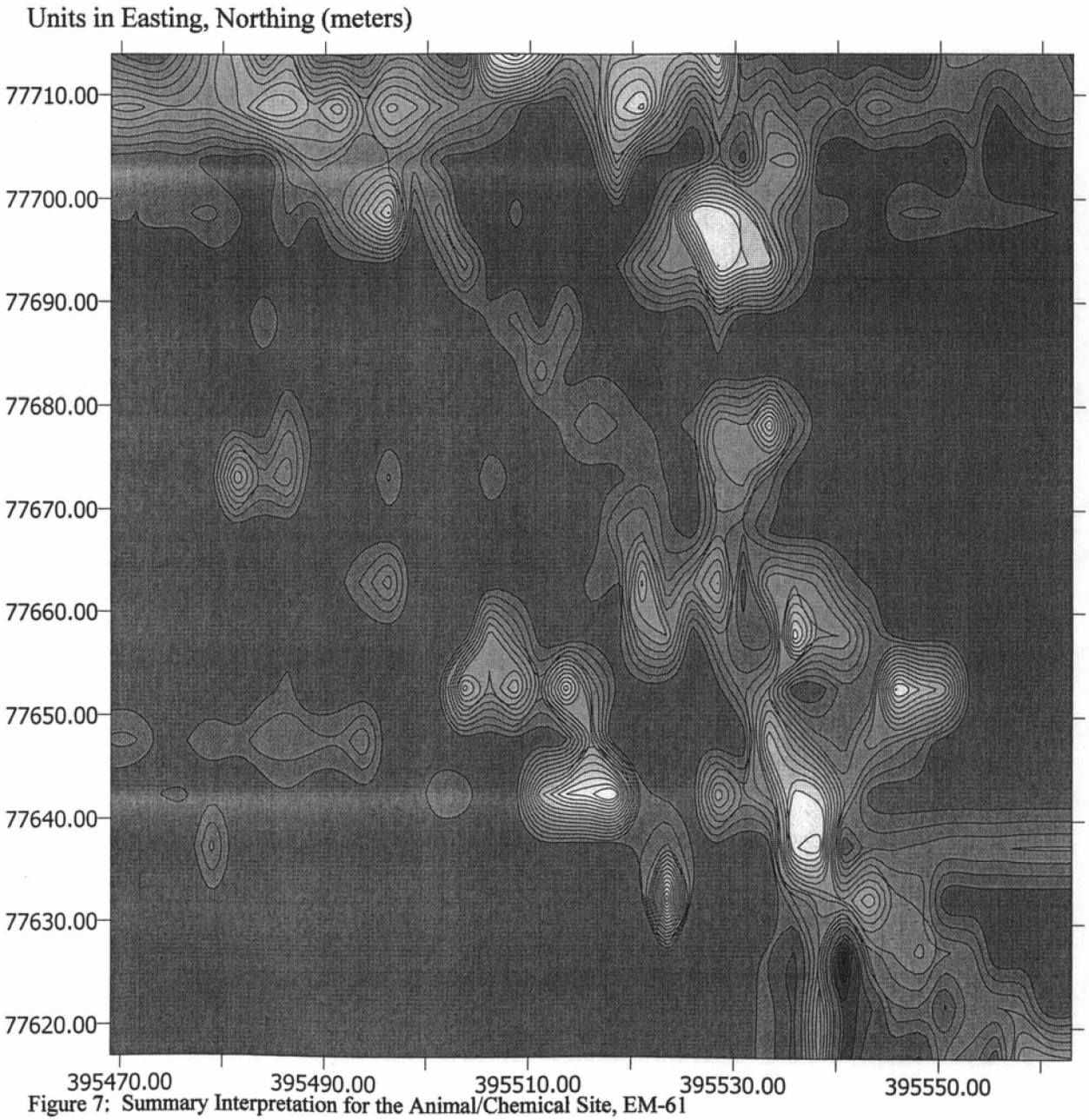

Figure 7: Summary Interpretation for the Animal/Chemical Site, EM-61

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